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ABSTRACT

A study charting the development of grade school children's analogic reasoning used 26 second, fourth, fifth, and sixth grade students from lower middle class and higher middle class schools. The children were asked to explain concrete, interactive, and abstract concepts to an imaginary creature (a puppet). For half the items, an initial period of spontaneous discussion was followed by questions that directed the children to make comparisons. Responses were examined for the number of analogies used, the degree of tension captured in the comparison, and the children's tendencies to explicate their comparisons. The results documented an increase with age in the number of analogies produced, the amount of tension present in the comparison, and the children's tendencies to explain their associations. A period of literalness and conventionality during the middle years of grade school was suggested by a drop in the creativity of spontaneous analogies by fourth grade students. These children showed more benefits from direct questioning than the older and younger subjects, who performed better in "freer" situations. Analysis of item types showed that concepts which presented a moderate but not insuperable challenge were most likely to encourage the production of analogies. (Author/RL)

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Technical Report No. 13

THE SPONTANEOUS PRODUCTION OF ANALOGIES BY GRADE SCHOOL CHILDREN

by

Eve Mendelsohn, Ellen Winner, Howard Gardner

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Abstract

A study was conducted in order to chart the developmental changes in grade school children's use of analogic reasoning. Subjects of two socio-economic classes from the 2nd, 4th, 5th, and 6th grades, were asked to explain concrete, interactive and abstract concepts to an imaginary creature (a puppet) from the planet Neptune. For half the items an initial period of spontaneous discussion was followed by questions which directly asked the child to make a comparison. Responses were examined for the number of analogies used, the degree of tension captured in the comparison, and the children's tendency to explicate their comparisons.

Results documented an increase with age in the number of analogies produced, the amount of tension present in the comparison, and the children's tendency to explain their associations. A period of literalness and conventionality during the middle years of grade school was suggested by a drop in the creativity of spontaneous analogies at grade 4. Children of this grade level benefited from direct questioning and a more defined context, whereas older and younger subjects performed better in a "freer" situation. Analysis of item types showed that concepts which present a moderate, although not insuperable challenge are most likely to encourage the production of analogies.

The Spontaneous Production of Analogies by Grade School Children

Eve Mendelsohn, Ellen Winner, Howard Gardner

Three year old Rachel sees another child with a freckled face and exclaims, "cornflakes". When four year-old Michael looks up and sees a plane making skywriting he says, "Hey, the sky has a scar on it." And three year-old Sarah calls a group of nuns in their black and white habits, "penguins".

In a few years these children will stop delighting us, and possibly themselves, with their charming and imaginative renamings. Their speech will become more conventional and more literal (Billow, 1977; Gardner, Kircher, Winner, & Perkins, 1975; Snyder, 1979). Why does this happen? Why do children in grade school cease creating these playful metaphors and insist, instead, upon a more limited use of language? And what, if anything takes the place of these renamings?

Based on observations of child speech, we hypothesized that this decline in metaphoric production may coincide with an increase in a different, more advanced, form of comparison, that of the analogy.* Compare the above examples with the following: Seven year-old Maria attempting to understand what it means for medicine to have side effects, asks "Is it like using scissors to open a can and bending them in the process?" Another grade schooler explains, "Cancer, that's something that your own body does - sort of like a mutiny." And Karen, age 11, explains to her younger brother why the temperature is reported in both centigrade and Fahrenheit, "It's a different language, but it says the same thing."

These comparisons differ from those of the preschoolers in several ways. Grade school children prefer to make explicit comparisons in the form of "A is like B" rather than to rename objects directly, as the preschoolers do (i.e., looking at "A", and calling it "B"). Furthermore, the comparisons of older children are no longer confined to perceptual similarity, (e.g., freckles are cornflakes) but are instead more abstract and are often based on relational similarities (e.g., It is the relationship of bent scissors to a can that is similar to the relationship between side effects and medicine).

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* The term "analogy" is used here to refer to comparisons based on a similarity existing between two pairs of elements. The four elements need not be directly put forth in the form a:b::c:d, but may be implied or infered. Furthermore, the comparison is explicitly stated by the use of a term such as "like" (e.g., A is like b).

While quite a bit is now known about the types of metaphors produced by preschoolers (Billow, 1977; Chukovsky, 1968; Winner, 1979; Winner, McCarthy, Kleinman, & Gardner, 1979) little is known about the types of analogical comparisons made by grade school children. Accordingly, we sought to gain a better understanding of grade schoolers' use of analogies: their ability to make comparisons as well as their natural tendency for doing so; the types of analogies children produce and the sorts of subject matter on which they base their comparisons.

In addition to establishing an overall picture of the nature of analogy production among children, we sought to secure information on a number of specific issues. One issue examined was the amount of tension or imaginativeness entailed in grade school analogies. Tension measures the conceptual distance between the elements being compared; the greater the distance the "tenser" and more pleasing the comparison.* In line with evidence that grade school children are hesitant to depart from conventional language use (Billow, 1977; Gardner, Kircher, Winner, & Perkins, 1975; Snyder, 1975), we hypothesized that grade school analogies would not be tense. However, with the proper encouragement (i.e. changing the rules) the ability to produce tense analogies would increase with age.

Understanding the contexts in which analogies are used and the functions which they serve is of further educational interest. Based on our observations, we hypothesized that children are most prone to use analogies when faced with understanding or explaining unfamiliar concepts. As children get older, they encounter increasingly abstract and complex ideas for which simple preschool renamings are not appropriate, thus we expected a turn to analogy.

The Study

With these issues and questions as a framework, we sought to chart the developmental course of analogy production in elementary school children. Our aim was to create a naturalistic situation in which children would be likely to use analogies. Based on our observations that analogies are used to help understand and explain novel ideas, we decided to approximate this real life situation by asking children to explain various concepts to an ignorant puppet from a distant planet.

Questions and Hypotheses

The study was designed to address the following questions:

1) Does the spontaneous production of analogies increase during grade school years?

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* For example, comparing a radio to a television crosses hardly any distance and is said to be not tense, whereas likening cancer to a mutiny requires a much greater domain leap and is considerably tense.

2) As children get older, are they able to create analogies with more tension -- that is, with a greater distance between the elements being compared?

3) If children do not produce analogies spontaneously, are they able to do so when explicitly asked to make a comparison? Do different types of questioning aid or inhibit analogy production?

4) Are children of different ages differentially able to explain the bases of their own analogies -- that is, to state the grounds of their analogies?

5) Do different types of subject matter elicit different kinds or amounts of analogies from children of varying ages? In particular, do abstract concepts (such as government) lead to more analogies than concrete ones (such as how a radio works)?

The following hypotheses were tested:

1) The spontaneous production of analogies will increase with age.

2) Older subjects will be able to produce anaologies of greater tension than will younger ones.

3) The use of probe questions (that is, directly asking the child "What's that like?") will increase analogy production at all ages; and more specific probes which suggest a second domain from which to make the comparison will be most likely to elicit analogies.

4) The ability to explicate the ground of analogies will increase with age.

5) The more difficult a concept is to explain, the more likely it is to yield analogies in the explanation; thus, abstract concepts will elicit the highest number of analogies and concrete objects the least.

Method

Subjects: Twenty-six children (selected at random from their classrooms), in each of grades 2, 4 and 6, and 16 children from grade 5, participated in the study. In order to assess social class differences, subjects were drawn from a lower middle class and an upper middle class school in the Boston area. Sixteen children from each of the four grades tested attended a public school in a lower middle class neighborhood. A smaller sample of 10 subjects from each of grades 2, 4, and 6 were drawn from a private school serving a primarily upper middle class population.

Materials and Procedure: Each child was seen individually in a quiet room for twenty to thirty minutes. Interviews were tape-recorded and transcribed for later analysis.

Children were introduced to a small hand puppet named "Maxwell". They were told that he had just arrived from the planet Neptune and knew nothing about life on earth. They were then asked to help Maxwell by explaining some things to him. A demonstration followed in which the experimenter explained a sample item (What is an egg?) to the puppet. The explanation included an abstract comparison (Cracking an egg is like opening a box.) and a perceptual one (A fried egg looks like a bull's eye.). Each subject was then asked to explain ten concepts to the puppet. For example, the child was instructed as follows: "I told Maxwell that someone had retired from a job and he didn't know what that meant. Would you tell Maxwell what it means for a person to retire from a job?" In an effort to elicit analogies, Maxwell asked leading questions during the explanations.

Children were asked to explain three types of items:

a) the functioning of concrete objects and processes, e.g., how a radio works. (four items)

b) interactions between people, e.g. telling a secret. (two items)

c) abstract concepts, e.g. what retiring means. (four items)

In order to tap the child's underlying ability to produce analogies, for half the items, two types of probe questions followed the initial, spontaneous response. The open probe consisted of asking the child to think of something "like" what he was describing (e.g. Can you think of anything else that's like retiring?). The more directed domain probe gave the child a specific domain from which to construct a comparison (e.g. Can you think of anything having to do with clothing that's like retiring?") A different domain probe was used for each item.

The ten items were divided into two equal groups (Group A and B), each consisting of two concrete items, two abstract items and one interaction item. Half of the subjects received probes for Group A items, half received probes for Group B items. In addition, half the children received the probed items first, and half received them last. Thus, there were four conditions:

1) Group A items without probe, followed by group B items with probe

2) Group A items with probe, followed by group B items without probe

3) Group B items without probe, followed by group A items with probe

4) Group B items with probe, followed by group A items without probe

The group of probed items was prefaced by a short introduction encouraging the child to "try to think of things that are like" what they were going to describe. The order of presentation of items in each group was counterbalanced across subjects.

Scoring and Analysis: Each analogy was scored as follows:

1) Item type: The type of item eliciting the analogy was noted (concrete, abstract or interactional).

2) Tension: Responses were scored as: a) very tense, original b) tense, not original c) somewhat tense d) not tense e) anomalous. In later analyses, this scale was collapsed into two categories: tense analogies (a & c) and non-tense analogies (b & d);* anomalous analogies were disregarded.

3) Ground: For each analogy it was noted whether the child supplied the ground and, if so, whether he offered it spontaneously or only after explicit questioning.

4) Spontaneous or probe: Whether an analogy was produced spontaneously by the child (i.e. during the initial explanation period), or as a result of one of the two kinds of probes, was noted.

Two sets of analyses were performed: In one analysis, both subject pools were combined but grade 5 was omitted; this was done because 5th graders were interviewed at only one school. In the other analysis, grades 2, 4, 5 and 6 from only the lower class school were analyzed. Results of the latter analysis will only be reported when they indicate patterns which are different from those in the combined analysis.

Results

Schools

On all measures, there were significant differences in performance between students in the two schools. In every probe situation, children from the private school gave significantly more analogies and more grounds than children from the public school; and their analogies were higher in tension. (For statistical results, see appendix) The overall character of the interviews differed strikingly between the two schools. Children from the private school approached the task in a far more relaxed, almost nonchalant, manner than did children from the public schools. The responses of the private school students were far more articulate, usually longer and they showed a greater familiarity with the specific items being discussed.

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* If an analogy was tense but not original, it could not be assumed that the child appreciated its tension, therefore analogies scored as type "b" (tense, not original) were considered not tense.

Sex Differences

Initial two-way (Sex x Itemtype), (Sex x Tension) and three-way (Sex x Itemtype x Probe) repeated measures analyses of variance for all measures in all three probe situations revealed no sex differences. This variable was, therefore, omitted from all further analyses.

Number of Analogies Produced: Effects of Age

The three probe situations summed: A three-way (Grade x School x Probetype) repeated measures analysis of variance was performed on the total number of analogies produced across all probe situations. A significant increase by grade was found ($F(2,69)=12.871$, $p \leq .001$). Post-hoc Newman Keuls tests revealed that the only significant pair-wise difference was between 2nd and 6th graders ($p \leq .01$).

Spontaneous: A three-way (Grade x School x Condition) repeated measures analysis of variance was performed on the number of analogies produced spontaneously. A significant increase by grade was found ($F(2,63)=9.065$, $p \leq .001$). Post-hoc Newman Keuls tests revealed a significant difference between both 4th and 6th graders and 2nd and 6th graders ($p \leq .01$), but not between 2nd and 4th graders. When the analysis was performed on only the public school scores, no effect of age was found. Thus, the grade effect found in the first analysis was due to the private school subjects.

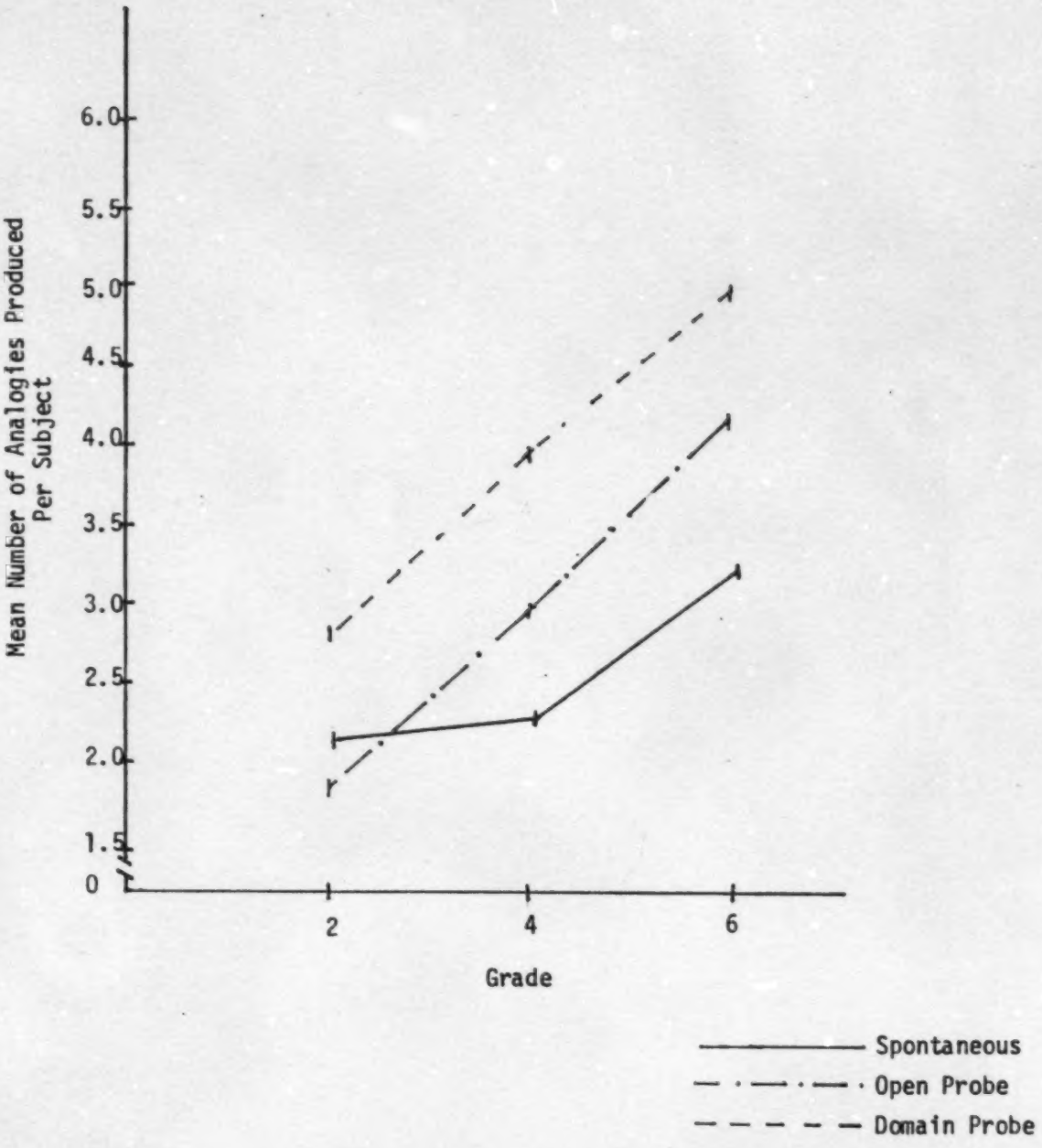
Open Probe: A four-way (Grade x School x Condition x Itemtype) repeated measures analysis of variance was performed on the number of analogies produced as a result of the open probe. A significant increase by grade was found ($F(2,63)=8.946$, $p \leq .001$). Post-hoc Newman Keuls tests showed no difference between 2nd and 4th graders or between 4th and 6th graders, but revealed a significant difference between 2nd and 6th grade scores ($p = .05$).

Domain Probe: A four-way (Grade x School x Condition x Itemtype) repeated measures analysis of variance was performed on the number of analogies produced as a result of the domain probe. Again, a significant increase by grade was found ($F(2,63)$ 9.313, $p \leq .001$). Post-hoc Newman Keuls tests revealed no difference between 2nd and 4th graders or between 4th and 6th graders. There was, however, a significant difference between 2nd and 6th grade scores ($p < .05$).

Summary: The above results demonstrate an increase with age in both the spontaneous tendency and the underlying ability of grade school children to produce analogies. While the ability to produce analogies when specifically asked to do so (as in the open and domain probe situations) increases fairly steadily with age, spontaneous analogy production increases more sharply between grades 4 and 6 than between grades 2 and 4. Figure 1 graphs the mean number of analogies produced in each probe situation by the three age groups. Furthermore, these skills seem to develop

FIGURE # 1

MEAN NUMBER OF ANALOGIES PRODUCED IN EACH PROBE SITUATION
FOR THE FIVE ITEMS WHICH WERE PROBED



at a faster rate among subjects from more socially advantaged backgrounds. Children from the public school showed a statistically nonsignificant increase with age.

In general, children did not use a great number of analogies. On the average, each child produced slightly more than eleven analogies for all ten items they were asked to discuss. Thus, it does not seem that grade school children have frequent recourse to analogies when presented with an explanation task of this type. The mean number of analogies produced per child at each age for the three probe situations appears on Table I.

Tension: Effects of Age

The three probe situations summed: A three-way (Grade x School x Probetype) repeated measures analysis of variance was performed on the percentage of tense analogies out of the total number produced, summed across all probe types. Although there was a significant increase by grade, ($F(2,69)=6.88$, $p=.003$), post-hoc Newman Keuls tests revealed no significant pair-wise differences.

Probes: Three separate three-way (Grade x School x Itemtype) repeated measures analyses of variance were performed on the percentage of tense analogies out of the total number of analogies produced in each probe situation (spontaneous, open probe and domain probe). A different developmental trend appeared for each probe:

In the spontaneous situation, there was an overall effect of age on the percentage of analogies which were tense ($F(2,69)=3.334$, $p=.042$). Fourth graders produced the lowest percentage and sixth graders the highest. Pair-wise analysis revealed no significant grade effects.

Some examples may help illustrate this trend. Fourth graders were more likely to stick to mundane and obvious comparisons in their spontaneous explanations. When asked to tell Maxwell what causes a flower to wilt, they offered comparisons such as "You drink water and that gives you water for your body. Well, when a flower gets water, it gives it water for its stem." In contrast, a 6th grader explained that flowers need vitamins and minerals from the dirt. "It's sort of like gas for a car because it makes you [flower] go and it keeps you [flower] alive." And a 2nd grader said, "Roots are the things that . . . a lot like wires: wires store electricity - let electricity run through it, it's almost the exact same thing except with water and rain." The above examples serve to demonstrate the general tendency, in the middle grade school years, for children to be more literal and less adventurous than either their younger or older school mates.

A significant effect of grade for the open probe situation ($F(2,69)=7.353$, $p=.002$) revealed a steady increase with age in the percentage of tense analogies. Again, there were no significant pair-wise effects. Grade did not prove significant in the domain probe analogies; however, a trend of increased tension in grade 4 was found.

Table I

Mean Number of Analogies Produced Per Child

Grade	Number of Spontaneous Analogies (10 Items)	Total Number of Spontaneous & Probed Analogies (10 Items)	Number of Spontaneous Analogies from Probed Items (5 Items)	Number of Analogies from Open Probe (5 Items)	Number of Analogies from Domain Probe (5 Items)
2	3.250	7.772	2.129	1.830	2.692
4	3.552	10.371	2.188	2.900	3.919
6	6.167	15.192	3.137	4.081	4.944
Average:	4.323	11.111	2.485	2.937	3.851

13

14

Summary: In sum, each probe resulted in a different developmental trend: for spontaneous analogies there was a dip in tension at grade 4; for open probe analogies there was a steady increase by age; and for domain probe analogies there was a peak at grade 4. Figure 2 plots the changes in tension across age for each probe situation.

These results suggest that 4th graders are more constrained and concerned with renaming within conventional category boundaries than are either their younger or older counterparts. In their spontaneous analogies, they tended to be less creative and imaginative and more conventional (i.e. less tense) than either 2nd or 6th graders. The different patterns which emerged from the three probe situations will be discussed in the following section.

The Effect of Probes

Number produced: The three-way (Grade x School x Probetype) repeated measures analyses of variance on the total number of analogies produced revealed a significant difference between the three probe situations ($F(2,138)$ 14.596, $p \leq .001$). Most analogies resulted from the domain probe (41% of all the analogies produced were in answer to a domain probe) followed by the open probe (32%) and then spontaneous analogies (27%). Post-hoc Newman Keuls tests revealed a significant difference at $p < .01$ in the number of analogies produced between the spontaneous and the domain probe situation and between the open probe and the domain probe situation. The interaction between probetype and age was not significant, suggesting that the three probe types did not differentially effect the three ages.

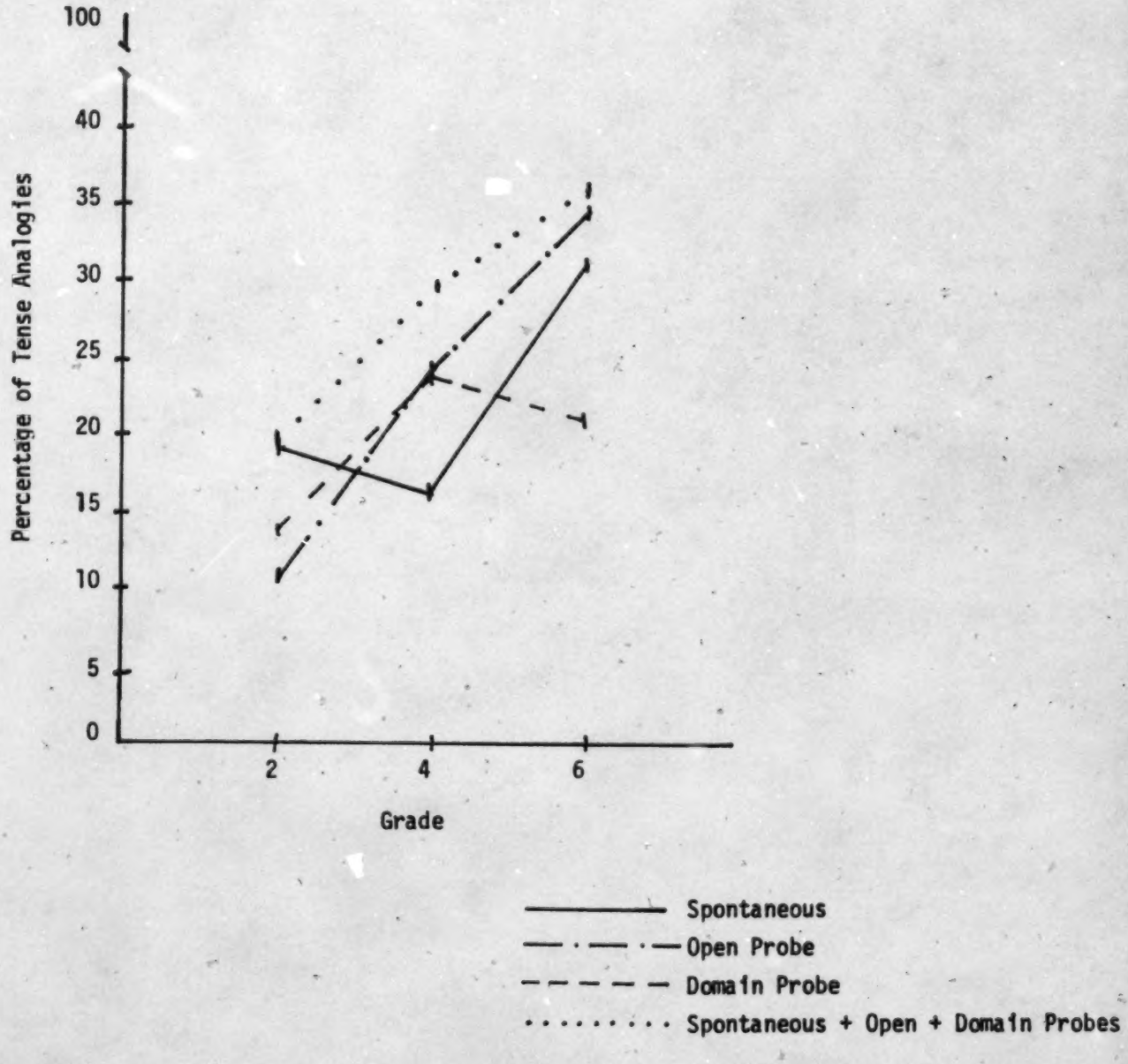
Tension: The three-way (Grade x School x Probetype) repeated measures analysis of variance on the percentage of tense analogies revealed no overall effect of probetype on tension and an interaction between age and probetype which almost reached significance ($p=.082$). As noted above, for spontaneous analogies tension dipped at grade 4; there was a steady increase in tension with age for open probe analogies, and a peak at grade 4 for domain probe analogies (see figure 2).

Summary: The fact that more analogies were yielded by the probes than by the spontaneous explanations indicates that grade school children's competence to produce analogies exceeds their spontaneous performance. The highly significant effect of the domain probe as compared to the minor effect of open probe demonstrates that more direct and focused questioning is more effective than an open-ended request for a comparison.

Although the use of probes did not significantly effect tension, the three different patterns which emerged are worthy of further discussion. As evidenced by the findings reported in the previous section (and illustrated in Figure 2), each probe situation yielded a different developmental trend. The scarcity of tense, spontaneous analogies among the 4th graders as compared to 2nd and 6th graders suggests that they are more constrained and literal than both younger and older children. However, the fact that the percentage of tense analogies increased steadily with age in the open

FIGURE #2

PERCENTAGE OF TENSE ANALOGIES
OUT OF THE TOTAL NUMBER PRODUCED
FOR EACH PROBE SITUATION



probe and peaked at grade 4 in the domain probe suggests that the more literal 4th graders are well able to produce tense analogies. However, they only appear to do so in more constrained situations in which the "rules of the game" call for such behavior. Thus, the more directive the probe, the tenser their analogies. The same 4th grader who offered only a rather uninteresting comparison between two living things (a human body and a plant stem both needing water) was able to create a much tenser analogy comparing an animate and inanimate object when given a domain probe: "pipes that give you water in the faucet is like the roots that give the flower water." The less literal 2nd graders on the other hand, produce tenser analogies in the "freer," spontaneous condition, and seem to be somewhat hampered by the directive probes. Finally, 6th graders occupy an intermediate position. They produce the highest number of tense analogies in the open probe, which serves to "remind" them of the task, but leaves available a broad realm from which to draw comparisons. The highly constrained domain probe, on the other hand, impedes the production of tense analogies among 6th graders.

Itemtype

Number produced, spontaneous: A five-way (Grade x School x Condition x Itemtype x Probe) repeated measures analysis of variance performed on the number of spontaneous analogies revealed a significant effect of itemtype ($F(2,126)=5.150$, $p=.008$). Forty percent of the spontaneously produced analogies resulted from interactions compared to 34% from concrete items and 26% from abstract ones. Post-hoc Newman Keuls tests revealed a significant pair-wise difference between abstract items and interactions ($p=.05$).

The analysis further revealed an interaction of grade with itemtype ($F(4,126)=3.883$, $p=.006$). Although the total number of analogies increased with age, 2nd graders produced a higher proportion of their analogies from abstract items and a lower proportion from concrete items than did the two older groups. Table II and Figure 3 show the proportion of spontaneous analogies resulting from each itemtype at each age level.

Number produced, open probe: A four-way (Grade x School x Conditions x Itemtype) analysis of variance on the number of analogies produced from the open probe also revealed a significant, but different, effect of item type ($F(2,126)=4.551$, $p=.013$). Here, concrete items elicited the most analogies (42%) compared to 32% for interactions and 26% for abstract items. Post-hoc Newman Keuls tests indicated a significant difference between the number of analogies resulting from interactions and concrete items ($p=.05$) and between abstract and concrete items ($p=.01$); the difference between abstract items and interactions was not significant.

In order to assess the effectiveness of the open probe in eliciting analogies, the number of analogies produced as a result of the open probe was compared to the number produced spontaneously for each item type. For concrete items, the open probe yielded three times as many analogies

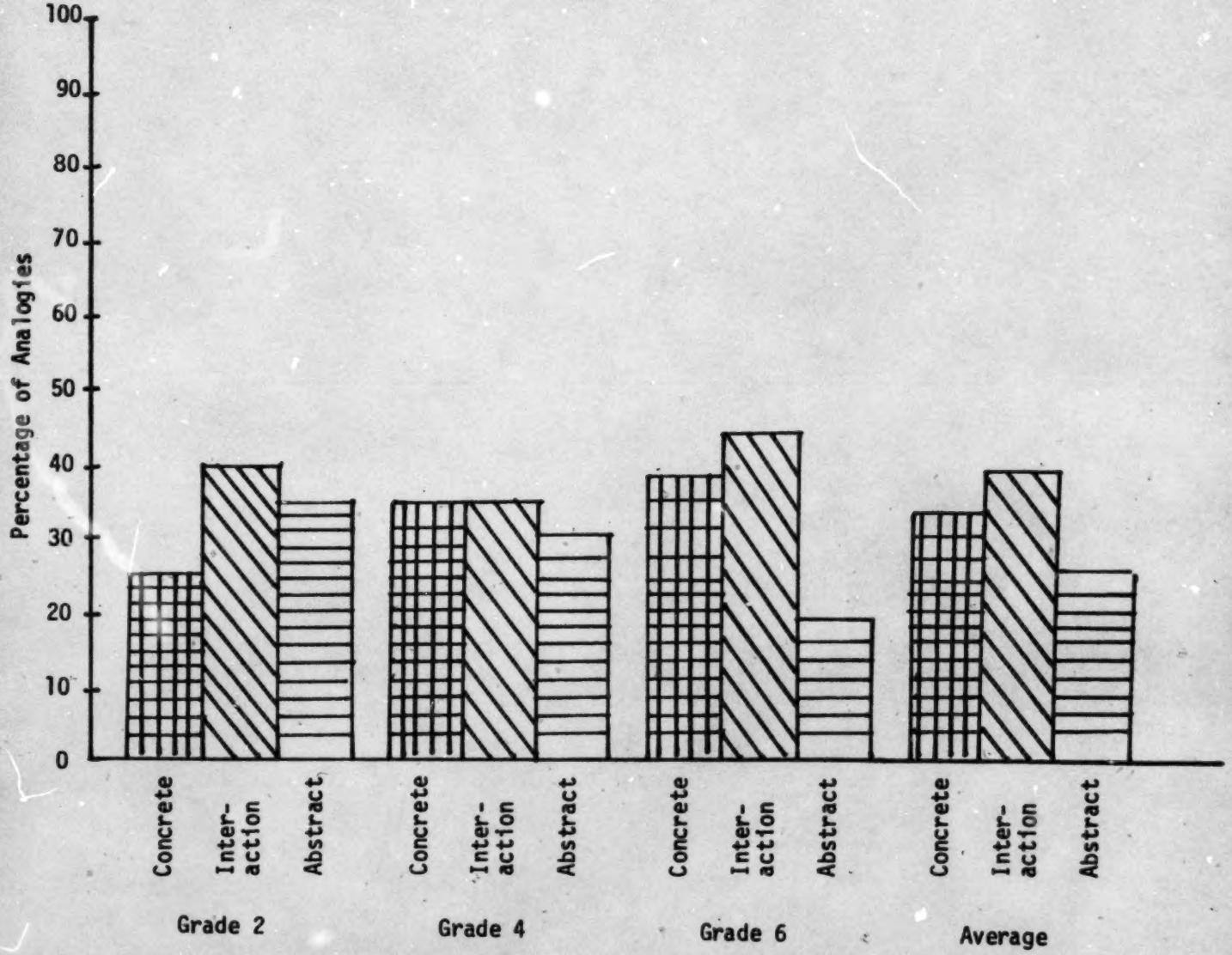
Table II

Percentage of Analogies Given for Each Itemtype Out of Total Number of Spontaneous Analogies

	Concrete	Interaction	Abstract	
Grade				
2	25	40	35	100
4	35	35	30	100
6	38	43	19	100
Average:	34	40	26	100

FIGURE #3

PERCENTAGE OF ANALOGIES GIVEN FOR EACH ITEMTYPE
OUT OF THE TOTAL NUMBER OF SPONTANEOUS ANALOGIES



as did the spontaneous situation. For abstract items, the open probe yielded 10% more; and for interactions, the open probe actually yielded 19% fewer analogies than yielded by the spontaneous situation.

Number produced, domain probe: The four-way (Grade x School x Condition x Itemtype) repeated measures analysis of variance was performed on the number of analogies elicited by the domain probe. Still another significant effect of itemtype ($F(2,126)=78.948$, $p \leq .001$) resulted. The greatest proportion of these analogies came from concrete items (60%) followed by abstract items (25%) and then interactions (14%). Post-hoc Newman Keuls tests revealed significant differences in the number of analogies produced for all pair-wise analyses ($p=.01$).

Tension: Three separate three-way (Grade x School x Itemtype) repeated measures analyses of variance were run on the percentage of analogies that were tense for each of the three probe situations. Results demonstrated a significant effect of itemtype only among spontaneous analogies ($F(2,138)=3.205$) $p=.044$). 28.5% of the analogies from abstract items were tense, compared to 25.4% from concrete items and 14.6% from interactions. Post-hoc Newman Keuls showed significant pair-wise differences between interactions and concrete items and between interactions and abstract items ($p=.08$) but not between abstract and concrete items.

Summary: The above patterns suggest that, contrary to hypothesis, grade school children are less likely to produce analogies when discussing abstract items than when dealing with concrete ones. This finding might be explained by the fact that concrete items and interactions are easier to talk about and explain than abstract ones which pose a greater challenge. It was observed that abstract concepts were often quite difficult for children and yielded minimum responses. However, as evidenced by the fact that abstract items yield the highest percentage of spontaneous tense analogies, it seems that when the child can produce analogies about abstract ideas, they are likely to be of better quality than those about more concrete concepts.

Some of the most imaginative analogies constructed at each age came from abstract items. Consider, for example the concept of a contagious cold: A 2nd grader said "It's like a ghost going through the air." Another child (grade 4) explained "....it's like a wave, like when you breathe it comes out and it's like a radio wave." And a 6th grader suggested "That's kind of like a sponge...because when you're sick people around you can get sick germs that you have and then they'll get sick." One might conclude that good analogies are most likely to be used when the task presents a moderate degree of challenge. When the task is too easy, the analogy is not needed and serves no purpose; when it is too difficult the child (or adult) is unlikely to be able to form a comparison.

The fact that 2nd graders produced relatively more comparisons from abstract items than did 4th or 6th graders lends more support to the existence of a "literal" stage among the older children. While older children tended to effect primarily concrete, logical and functional

comparisons (e.g. "...your body needs vitamins like a car needs gasoline (Grade 6)); younger children were apt to produce more fanciful analogies in addition to the rather "straightforward" ones [e.g., When you cook a piece of steak it gets a "pretty good tan" (Grade 2); Cold germs going through the air is like "a ghost going through the air. Because you can't see it..." (Grade 2)].

In the open probe, in which children were explicitly asked to make a comparison, children devised the highest number of analogies about concrete items. The fact that three times as many analogies resulted from the open probe than the spontaneous situation indicates that children are capable of producing the analogies for these items but choose not to do so on their own accord. Perhaps the items were easy enough to explain and comparison was not necessary or useful.

The open probe increased analogy production less for abstract items and decreased it for interactions. There are at least two competing explanations for this finding: 1) The items were so difficult that, even when asked, children could not make comparison 2) The analogy production had already occurred in the spontaneous explanation; and the probe was therefore less effective. Given the overall paucity of analogies from abstract items, the first theory seems more plausible. For interactions, where more analogies were produced spontaneously, the latter explanation may apply.*

Grounds

A three-way (Grade x School x Condition) repeated measures analysis of variance was performed for each probe situation on the number of analogies for which a ground was offered spontaneously. In each situation, there was a highly significant increase with grade [Spontaneous analogies: $F(2,61)=14.442$, $p \leq .001$, Open probe analogies $F(2,63)=8.275$, $p \leq .001$, Domain probe analogies: $F(2,63)=10.030$, $p \leq .001$]. As was expected, with age, children were more apt to explain their analogies.

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* Only limited weight should be placed on the varied effects of the domain probe. Since each item had a different probe, it is difficult to determine whether the findings reveal actual differences in the ability to produce analogies or result from inherent differences in the domain probes themselves. Some of the probes were quite specific and "obvious" (e.g., "Can you think of anything having to do with clothing that is like retiring?") and, therefore, often produced analogies. Others were more general and led to fewer analogies (e.g., "Can you think of anything that might happen in your house that is like catching (a cold)?").

Condition

The five-way (Age x School x Condition x Itemtype x Probetype) repeated measures analysis of variance performed on the number of spontaneous analogies produced revealed a significant effect of condition ($F(1,63)=4.838$, $p=.032$). When the probed items came first, significantly more spontaneous analogies were produced than when the probed items came second. Thus, one can conclude that the probe helped elicit spontaneous as well as non-spontaneous analogies.

Discussion

Some comments about the atmosphere of the study seem appropriate. In general, children seemed to enjoy their session with the puppet, although individual differences were apparent in how each child approached the task. At each age, some children became quite engaged in the role of "teacher", accepted Maxwell, directed their responses to him and even, at times, asked him questions. Others virtually ignored the puppet and spoke directly to the experimenter. There were also individual differences in the amount of analogy production. Some children were able to create numerous analogies with seemingly little effort (sometimes as many as five comparisons for one item); others of the same age, for whom the strategy seemed foreign and difficult, used no analogies.

Of further interest is the great variety in the content of the interviews. There was a wide range in the amount of information children offered about the various concepts they were asked to explain. Their responses reflected impressive knowledge, as well as alarming ignorance and some charming misconceptions. For example, when asked what "government" is, one precocious 2nd grader offered an explanation of President Carter's energy policy, while a 4th grader maintained that the president owns the whole world; and a 6th grader explained that the government balances the budget by making sure there is an equal amount of money on the East coast and the West coast. It should be added that there were some children who were unable to talk about government altogether.

Turning to the study itself, the results supported most of the hypotheses: The spontaneous production of analogies does increase with age. As children get older they are capable of producing analogies of greater tension and are more likely to explicate their analogies. Explicit requests to make comparisons (i.e. probe questions) increase analogy production and more specific and directed questions (i.e. domain probes) help elicit even more analogies.

A number of findings ran contrary to expectations. To begin with, abstract items elicited fewer analogies than did concrete items or interactions. It should be noted that the analogies about abstract items were more likely to be tense than were analogies from the other two item types. Furthermore, the interaction of probe with items type, showed that probes were most effective for concrete items and least effective for interactions. The open probes also exerted interesting effects on tension. These probes

had a strong positive effect on analogy production among 4th graders, only a slight effect for 6th graders and a negative effect for 2nd graders. Thus, while the study as a whole documented the expected improvement in skill with age, a number of more specific findings reveal a complex trajectory of development in the realm of analogic competence.

Taken together, the results of the study offer information of both theoretical and educational interest. The relative paucity of spontaneous analogies as compared to those elicited by probes indicates that children's competence to create analogies exceeds their spontaneous performance. Children seem to make best use of analogies in order to clarify concepts that they partially understand. A partially grasped concept can be further clarified by likening it to an already familiar, yet similar one.

The study provides more evidence in support of a literal stage in the mid-elementary school years: although grade school children produce more analogies as they get older, there is a dip during the middle years of school in the inventiveness of these analogies. Furthermore, older children are less likely than younger ones to produce analogies about abstract and intangible concepts. These findings suggest that the youngest grade schoolers are least inhibited in exhibiting their imaginative powers. As they get older, this spontaneity becomes somewhat stifled. If, the proper atmosphere is created, however, that is if the "rules of the game" permit, their imaginations are released. Children of the middle grade school years seem to need even more direction and context in order to unlock this creativity.

Nonetheless, in the appropriate context and with the proper structure, when a child is faced with a moderate challenge, comparison and analogy can be a constructive device for explaining and understanding new concepts.

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Appendix

School Effects

Total number of analogies: $F(1,69)=40.621$ $p \leq .001$
school x probetype: $F(2,138)=7.140$ $p = .002$

Number of spontaneous analogies: $F(1,63)=50.109$ $p \leq .001$

Number of open probe analogies: $F(1,63)=8.209$ $p=.006$

Number of domain probe analogies: $F(1,63)=12.295$ $p=.001$

Percentage tense analogies

- from total number: $F(1,69)=9.100$ $p=.004$
- from spontaneous: $F(1,69)=12.044$, $p=.001$
- from open probe: $F(1,69)=9.775$, $p=.003$
- from domain probe: $F(1,69)=2.452$, $p=.122$*

Number of grounds given spontaneously

- for spontaneous analogies: $F(1,61)=54.528$, $p \leq .01$
- for open probe analogies: $F=(1,63)=8.698$, $p=.005$
- for domain probe analogies: $F=(1,63)=7.375$, $p=.009$

* not significant

Harvard Project Zero is a basic research program at the Harvard Graduate School of Education. Its original charge was to study creation and comprehension in the arts and means toward better art education. A prime objective throughout the Project's history has been to provide a sound theoretical and experimental base for effective education of artists and audiences. The Project began in the fall of 1967 in response to the frank admission that, however much is known about how to educate in science and how to evaluate scientific work, practically nothing is known about the underlying principles of how to teach and evaluate in art. From that challenging "zero" the Project took its name and tasks. Our research methods include rigorous conceptual analysis, investigation of relevant literature, design and execution of key experiments in psychology and other fields, visits to arts education institutions, and application of results to proposing and assessing programs in art education.

Project founder and former director Nelson Goodman's book Languages of Art (Bobbs-Merrill, 1968) has provided important direction in our effort to isolate and investigate basic skills. This work sets forth a "theory of symbols," a broad treatment of elements of communication, embracing words, gestures, diagrams, paintings, poems, musical scores, and so on. Almost all the psychological processes under consideration in our studies of the arts involve extensive operation with and upon symbols of various kinds. These symbols are not merely instruments of communication, but also instruments of cognition, tools in terms of which the mind deals with the perceptual world.

Some of our research has examined the psychological implications of the theoretical models of symbol systems introduced in Languages of Art. For instance, one question is whether different information processing skills are necessary to produce effective art within linguistic, versus nonlinguistic, symbol systems. Another, complementary approach emphasizes problem solving and search strategies in the moment-to-moment perception and production of a work of art. How do subjects search for rhyme words in poetry or explore alternative placements of pieces in collage? A favorite means of developing and testing new models is through the study of errors. By using impoverished or ambiguous stimuli, assigning tasks somewhat too difficult for a subject, or working with brain-damaged subjects, one can elicit patterns of error-making which suggest hypotheses and select between alternative models of a process. These approaches characterize many of the Project's investigations mentioned below in a list of Project members and their particular interests.

Though the development of actual curricula in arts education is not a primary concern, the Project does contribute to the field of practical education. Project members have responded to inquiries and requests to comment on curricula from teachers in the field. Establishment of Harvard Summer School's Institute in Arts Administration resulted from the Project's reply to an inquiry from the director of the Harvard Summer School, and members of the Project staff cooperated in planning the Institute, in preparing material, and in the actual teaching. Consideration consultation has been provided to schools, museums, television, and a variety of arts institutions by members of the Project.

The Project has also sponsored a series of lecture-performances in various media, designed to give the general public and prospective public school teachers and administrators better insight into and attitudes towards artists and the arts. As the series title "Art in the Making" suggests, the purpose of the lecture-demonstrations was to reveal something of the artist's way of working, rather than to display his products. In the presence of an audience free to ask questions, each artist explored alternatives, exposed some constraints of his medium, compared his various efforts, and searched for the right effect, choice by choice.

While maintaining a major concern with the arts and art education, the Project, under its current co-directors, has considerably broadened its field of inquiry and now investigates a whole range of topics in the area of cognitive psychology. One part of the Project has focussed particularly on developmental studies. Among the topics currently being investigated are the emergence of symbolic capacities during the first years of life; the development of literary abilities, specifically the capacity to produce and appreciate metaphors and stories; children's understandings of the various worlds presented on television; the emergence of drawing skills; and the breakdown of various symbol using capacities under various forms of brain damage. The other part of the Project has concentrated on studies in the areas of cognitive and perceptual psychology, ones which utilize both normal adult subjects and gifted artists. Among the topics investigated recently have been critical judgment and the sources of critical disagreement in adults; the thought processes of professional and amateur poets and painters in developing works; the role of geometric principles in visual perception and picture perception particularly; reasoning about everyday matters and the logical difficulties people encounter.

A list of recent papers which can be purchased from the Project is available upon request.